Association of dietary inflammatory index (DII) with Hypertriglyceridemic Waist Circumference Phenotype among Overweight and Obese Women: A cross sectional study

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Research Article

Keywords: Dietary inflammatory index, Hypertriglyceridemic waist circumference phenotype, obesity

Posted Date: March 16th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-332032/v1

Abstract

Aims: Recent studies have shown that increased dietary inflammatory index (DII) score or consumption of pro-inflammatory foods can lead to increased waist circumference (WC) as well as triglyceride (TG) concentrations in obese people. The purpose of this study is to examine the association between DII and hypertriglyceridemic waist circumference phenotype (HTGWCP) in overweight and obese women.

Methods: This study was performed on 226 obese women aged from 18 to 48 years. We evaluated DII score by semi-quantitative food frequency questionnaire (FFQ) of 147 items. Biochemical parameters were measured and anthropometric assessments were performed.

Results: There was a positive significant correlation between DII and HTGWCPs. In other words, with an increase in DII score, the odds of having abnormal phenotypes including; enlarged waist normal TG (EWNT) (OR=2.85, 95% CI=1.02 to 7.98, P for trend=0.04) , normal waist enlarged TG (NWET) (OR=5.85, 95% CI=1.1 to 31.11, P for trend=0.03), enlarged waist enlarged TG (EWET) (OR=3.13, 95% CI=0.95 to 10.27, P for trend=0.05) increase compared to normal waist normal TG (NWNT) phenotype.

Conclusion: Increasing DII scores can increase abnormal phenotypes so may increase WC and TG levels in overweight and obese women.

Introduction

Obesity is an important public health issue in most high-income countries as well as developing countries and it is emerging as a threat in more affluent sectors of developing countries [1]. According to the World Health Organization (WHO) in 2008, more than10% of the world's adult population i.e. about 500 million people were obese [2]. It was estimated 3.4 million people who died in 2010 were overweight or obese. This issue is associated with chronic diseases including; cardiovascular disease (CVD), diabetes, breast and endometrial cancer in women [1]. Obesity is usually caused by the accumulation of excess fat over the body and it is often characterized as a state of low-grade chronic inflammation [3]. Accumulation of fat in in visceral adipose tissue is associated with higher health risks [4].

Many studies have shown an association between diet and inflammatory markers of how multiple diets increase or decrease inflammation, as well as chronic inflammatory-related diseases such as obesity [5–7]. Some healthy dietary patterns, such as the Mediterranean diet (MeDiet), can reduce the low-grade inflammation observed in obese persons due to some of their components are known as an anti-inflammatory dietary pattern [8–11]. The DII as a new tool to assess inflammatory potential of the diet determines the inflammatory potential of the diet on a continuum from maximally anti- to pro-inflammatory [12]. The results of a study showed that DII was directly associated with the incidence of obesity, especially abdominal obesity in women compared to men and participants with higher BMI, WC, waist-to-height ratio (WHtR) had higher pro-inflammatory diet. According to results of this study, DII was inversely related with the consumption of anti-inflammatory nutrients and food and adherence to the MeDiet. The mechanisms underlying this association is the activation of pathogen-associated molecular

patterns, such as Toll-like receptors and Nod-like receptors, which activate inflammatory processes in adipose tissue [13, 14]. A review study concluded that unhealthy diets such as the Western diet, which are associated with higher inflammation, increased metabolic syndrome (MetS) components, such as WC and TG levels, compared with healthy dietary patterns, such as the Mediterranean diet, which were associated with lower inflammation [5]. Several investigations resulted that the inflammatory properties of the diet were associated with higher TG and lower high-density lipoprotein (HDL) plasma levels [15, 16]. The HTGWCP is defined as high serum TG levels and simultaneous presence of high WC and also it is a marker for assessing visceral obesity and low-grade inflammation status such as obesity and this phenotype is correlated with MetS components [17].

There is no investigation on the association between DII and HTGWCP and also by considering the relationship between DII and hypertriglyceridemia and high WC, we aimed to evaluate the relationship between DII and HTGWCP among obese and overweight women.

Subjects, Materials And Method

Study population

The protocol was accepted by the Ethical Commission at Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1399.636) and all participants signed a consent form.
The protocol was accepted by the Ethical Commission at Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1399.636) and all participants signed a consent form.
In this study, 226 women aged 18 to 48 years were required in. The study population was collected from across the regions of Tehran, using community-based sampling according to cluster sampling. The body mass index (BMI) range for women participants was between 25 to 49.6 kg/m^2. Moreover, In the our study, participants were chosen based on the following inclusion criteria: aged 18 to 48 years, being overweight or obese (BMI $\geq$ 25 kg/m^2) and exclusion criteria were as follows: being menopausal, history of hypertension, cardiovascular disease, kidney or liver disorders, diabetes mellitus, chronic diseases that affect a person's diet, body weight fluctuations over the past 1 year, following patterns and special diets and non-routine diets, women that their energy intake was less than 800 kcal or more than 4200 kcal, alcohol consumption, smoking and pregnancy or lactation period. The protocol was accepted by the Ethical Commission at Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1399.636) and all participants signed a consent form.

Anthropometric assessment

Body composition components including; skeletal muscle mass (SMM), Fat free mass (FFM), waist hip ratio (WHR); evaluated using a body composition analyzer (InBody770 scanner; InBody, Seoul, Korea). Prior to the assessments, according to the instructions of the manufacture, participants were asked to remove all metal tools with them, including jewelry and also to be placed on the device with the least clothes and without shoes or socks. No extreme physical activity was performed before the assessments,

and individuals were adequately rested. In using this device, how to stand and grab the metal handles of the device was done according to the manufacturer's instructions [18]. Weight was measured with the use of a digital scale (Seca, Hamburg, Germany) in light clothing and without shoes to the nearest 0.1 kg. Also, height was measured using a calibrated height gauge with a precision of 0.5 cm (in the standing position without shoes to the nearest 0.01 m). WC and hip circumference (HC) were measured in the smallest girth and the largest girth, respectively, with accuracy nearest to 0.1 cm. BMI was calculated as weight (kg) to height (m^2) ratio.

Biochemical assessment

Blood samples were taken after10–12 h of overnight fasting and the serum was centrifuged, liquated and stored at a temperature of − 80°C. All samples were analyzed by using a single assay according to manufacturer's protocol. All measurements were taken at the Biochemistry Laboratory of School of Health, Tehran University of Medical Sciences. Fasting plasma glucose was measured by using a glucose oxidase method and insulin level was assessed by using an enzyme-linked immunosorbent assay (ELISA) kit (Human insulin ELISA kit, DRG Pharmaceuticals, GmbH, Germany). Total cholesterol (T-Chole), TG, HDL-C and Low-density lipoprotein (LDL) were evaluated by using of enzymatic approaches and related kits (Pars Azemun, Iran) and auto analyzer system. The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) standardization for liver enzymes including; SGOT (serum glutamic-oxaloacetic transaminase) and SGPT (Serum glutamic-pyruvic transaminase) was used. The Homeostatic model assessment for insulin resistance (HOMA-IR) was computed as the product of fasting glucose and insulin level divided by 22.5 with molar unit (mmol/L)

Other variables

Demographic information

In this study, qualitative variables such as education, job, marital status, economic status and familial obesity history were assessed using a demographic questionnaire.

Physical activity assessment

Physical activity level was measured by a validated International physical activity questionnaire (IPAQ), the complex questionnaires that are designed to collected information based on leisure, activities at work, commuting, and housework especially for research purposes. These questionnaires can be used by person with an age range of 18 to 65 years old. Weekly physical activity was assessed by a 9 items form that was applied according metabolic equivalent (MET) scores for each type of activity. According to the IPAQ scoring protocol, MET scores were demonstrated as 3 and 6 METs for moderate activities and as 6 METs for severe activities. For reporting the total physical activity, MET scores were summed and MET-minutes per week (MET-min/wk) were reported [19, 20].

Dietary inflammatory index

DII is used as a tool to measure the diet's inflammatory potential on a continuum from maximally anti-inflammatory to maximally pro-inflammatory. A higher DII score or more positive DII indicates a diet with more inflammation-causing food and a lower DII score or more negative DII indicates a diet with less inflammation-causing food. Dietary intake was evaluated by using a semi-quantitative FFQ with 147 Iranian food items, containing a list of foods with their standard serving sizes that assesses the usual food intake over the previous year. The reliability and validity of this questionnaire have been confirmed [21]. Software program Nutritionist IV was used for nutrient analysis which was modified for Iranian foods. DII was computed based on Shivappa et al and Esfahani et al methods [22, 23]. To calculate DII for all participants, first, the Z-score was computed by subtracting the global standard mean from the amount reported by participants and dividing the difference by the global standard deviation. Then, the Z-score was converted to a centered percentile score. The centered percentile score of participants for each food parameter was multiplied by the food parameter effect score, to obtain a DII score for an individual. To create the overall DII score, all of the food parameter-specific DII scores were summed. Anti-inflammatory foods were used in this study included: dietary fiber, n-6 fatty acids, n-3 fatty acids, mono-unsaturated fatty acids, poly-unsaturated fatty acids, thiamin, riboflavin, niacin, vitamin B-6, folate, vitamin A, β-carotene, vitamin D, vitamin C, vitamin E, zinc, magnesium, selenium, onion, tea, and garlic and pro- inflammatory foods included: trans fatty acids, saturated fatty acids, protein, vitamin B-12, iron, total fat, energy intake, carbohydrate, and cholesterol.

Hypertriglyceridemic waist circumference phenotype

The HTGWCP was created by considering serum triglyceride concentration and WC and women were categorized in 4 phenotype groups on the basis of the mentioned cutoff points: NWNT: Normal WC < 88 cm and normal serum triglyceride concentrations < 150 mg/dl), EWNT: Enlarged WC ≥ 88 cm and normal serum triglyceride concentration < 150 mg/dl), NWET: Normal WC < 88 cm and elevated triglyceride ≥ 150 mg/dl, EWET: Enlarged WC ≥ 88 cm and hyper serum triglyceride concentration ≥ 150mg/dl [24].

Statistical analyzes

The normal distribution of data was checked by Kolmogorov Smirnov test. We used mean and standard deviation to describe quantitative variables and reported number and percentage for describing of qualitative data. DII score was categorized into Tertile (T) including T1 (more anti-inflammatory foods), T2 (intermediate group) and T3 (more pro-inflammatory foods) and as described, we made four phenotypes to examine the HTWP including; NWNT, EWNT, NWET, EWET. Calculating of relationships between DII and HTGWCP and quantitative variables and also the relationship between phenotype tertiles and food components were performed by analysis of variance (ANOVA) test and the results were adjusted for multiple comparisons using the tukey's post hoc test. Chi-square test was used to compare the differences between DII and HTGWCP and qualitative variables. Analysis of covariance (ANCOVA) was then used to find the difference between the means of investigated variables across DII and HTGWCP groups and adjusted for age, energy intake, BMI and physical activity. Associations between DII and HTGWCP were assessed in Multinomial logistic regression to adjust for confounder factors including; energy intake, age, insulin plasma level, marital status, education, economic status and Family

history of obesity. We considered the group of “NWNT” about HTGWCPs as reference Statistical analyzes were performed using IBM SPSS version 25.0 (SPSS, Chicago, IL, USA). The level of significance was considered as being a P value ≤ 0.05 for all analyses.

Result

Study population characteristics

A total of 226 adult women aged 18–48 years were recruited in the study. The mean (± SD) of age, BMI, weight, WC and WHR were 36.67 ± 9.10 years, 31.26 ± 4.29 kg/m^2, 81.29 ± 12.43 kg, 99.61 ± 10.07 cm and 1.16 ± 4.45 respectively. HTGWCP was categorized into four phenotypes. NWNT, EWNT, NWET, EWET phenotypes included 6.2%, 42%, 5.9, 45% of individuals respectively. 70.8% of women were married, 84.7% of them had a university education and 61.9% of them were unemployed.

The association between DII and quantitative and qualitative variables has been shown in Table 1. After controlling the confounding variables including age, energy intake, BMI and physical activity: A significant marginal correlation was found between age and DII, and this variable had a higher mean in the second tertile of DII (P = 0.08). A significant marginal correlation was found between HOMA-IR and DII and this relationship was negative (P = 0.09) and TG levels had a significantly higher mean in the second tertile of DII (P = 0.02).

Table 1
Description of characteristics among tertiles of DII

Variables	T1 N = 76	T2 N = 77	T3 N = 73	P value*	P value**
Age (year)	37.03(8.52)[a]	37.06(8.22)	34.82(8.43)	0.12	**0.08**
PA (MET h/week)	1200.87(1376.69)	1173.54(1555.11)	1143.56(2725.58)	0.98	0.97
Blood parameters					
FBS (mg/dL)	85.74(8.06)	88.51(10.31)	87.22(10.50)	0.21	0.13
Insulin (µIU/ml)	1.26(0.23)	1.24(0.21)	1.22(0.25)	0.63	0.99
HOMA-IR	3.63(1.62) [3]	3.19(1.25)	2.87(0.93)[1]	**0.02[a]**	**0.09**
TC (mg/dL)	184.02(39.14)	188.66(33.93)	182.42(35.14)	0.54	0.42
HDL-C (mg/dL)	47.37(13.06)	46.01(10.10)	46.77(10.38)	0.75	0.74
LDL-C (mg/dL)	95.12(26.36)	97.12(23.05)	91.69(21.95)	0.36	0.25
TG (mg/dL)	145.91(68.73)	108.09(43.03)	108.84(61.55)[1,2]	**0.002[b]**	**0.01**
SGOT (mg/dL)	17.00(5.99)	18.54(9.19)	17.93(6.68)	0.44	0.42
SGPT (mg/dL)	17.60(9.72)	20.20(16.12)	19.42(11.63)	0.44	0.49
Body composition parameters					
BMI (kg/m^2)	31.09(3.88)	30.37(4.65)	31.25(4.10)	0.33	0.11
SMM (kg)	25.67(2.98)	25.54(3.29)	25.66(3.82)	0.96	0.95
FFM (kg)	46.74(5.02)	46.60(5.58)	46.72(6.49)	0.98	0.94
WHR	1.94(9.59)	0.93(0.05)	0.93(0.05)	0.37	0.85
WC (cm)	98.97(9.45)	97.76(10.19)	99.52(10.18)	0.48	0.38
Qualitative variables					
Economic status					
Poor	12(41.4%)[b]	6(20.7%)	11(37.9%)	0.67***	0.77
Moderate	33(34.8%)	31(33.9%)	36(31.3%)		
Good	29(34.3%)	31(31.3%)	29(34.4%)		
Excellent	1(12.5%)	4(50%)	3(37.5%)		

Variables	T1 N = 76	T2 N = 77	T3 N = 73	P value*	P value**
Education status					
Illiterate	1(33.3%)	1(33.3%)	1(33.3%)	0.46	0.37
Diploma	14(38.9%)	7(19.4%)	15(41.7%)		
University educated	74(33%)	79(35.3%)	71(31.7%)		
Marriage status					
Single	14(26.8%)	20(39.3%)	19(33.9%)	0.38	0.17
Married	67(35.7%)	60(31.4%)	63(32.9%)		
familial obesity history					
Yes	55 (34.7%)	56 (34.2%)	51 (31/1%)	0.24	0.16
No	21 (27.3%)	18 (31.2%)	25 (41.6%)		
Hypertriglyceridemic waist circumference phenotype					
NWNT	3(16.7%)	5(27.8%)	10(55.6%)	0.26	0.19
EWNT	21(29.2%)	30(39.3%)	23(31.5%)		
NWET	7(30.4%)	8(34.8%)	8(34.8%)		
EWET	44(38.6%)	30(30.0%)	37(31.4%)		

[a]Mean±SD; [b] N(%); DII: dietary inflammatory index, PA: physical activity, FBS: Fasting blood sugar, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance, TC: total cholesterol, HDL-C: high density lipoprotein cholesterol, LDL-C: low density lipoprotein cholesterol, TG: triglyceride, SGOT: serum glutamic-oxaloacetic transaminase, SGPT: Serum glutamic-pyruvic transaminase, BMI: body mass index, SMM: Skeletal muscle mass, FFM: fat free mass, WHR: waist to hip ratio, WC: waist circumference, NWNT: normal waist normal triglyceride, EWNT: enlarged waist normal triglyceride, NWET: normal waist enlarged triglyceride, EWET: enlarged waist enlarged triglyceride

**P value resulted from ANOVA analysis*

*** P value reported after adjusting age, energy intake, BMI and physical activity with ANCOVA*

**** P value resulted from chi-squared test analysis*

T1, T2 and T3 are DII tertiles

The association between HTGWCPs and quantitative and qualitative variables has been shown in Table 2. It was shown that after adjustment for confounders including; age, energy intake, BMI and physical activity through ANCOVA test insulin ($P = 0.01$), HOMA-IR ($P < 0.001$), TG ($P < 0.001$), weight ($P < 0.001$), height ($P < 0.001$), BMI ($P < 0.001$), SMM ($P = 0.002$), FFM ($P < 0.001$), WHR ($P < 0.001$) and WC ($P < 0.001$)

were all significant with HTGWPs and TG concentrations, weight, BMI, SMM and FFM were higher in EWET phenotype, insulin and HOMA-IR were higher in NWET phenotype and height, WHR and WC were higher in EWNT phenotype.

Table 2
Description of characteristics among types of hypertrigeliceridemic waste phenotype

variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWNT	NWET	EWET		
	N = 15	N = 88	N = 14	N = 109		
Age(year)	32.08 ± 8.08[a,4]	36.87 ± 9.78	36.20 ± 7.18	37.17 ± 8.66[1]	**0.06**	0.17
PA (MET h/week)	682 ± 832.81	973.86 ± 1158.23	1972 ± 4117.85	1277.48 ± 2171	0.29	0.22
Blood parameters						
Insulin (µIU/ml)	1.21 ± 0.18	1.19 ± 0.23[4]	1.37 ± 0.18	1.29 ± 0.24[2]	**0.01**	**0.01**
HOMA-IR	3.32 ± 1.35[4]	3.09 ± 1.03[3,4]	4.72 ± 1.32[2]	4.14 ± 1.56[1,2]	**< 0.001**	**< 0.001**
TC (mg/dL)	168.81 ± 26.56	188.05 ± 38.15	173.37 ± 29.49	187.70 ± 35.52	**0.06**	0.73
HDL-C (mg/dL)	49.56 ± 10.71	45.75 ± 11.16	46.66 ± 11.51	46.74 ± 10.60	0.63	0.97
LDL-C (mg/dL)	86.68 ± 18.82	94.70 ± 26.51	93.41 ± 20.33	97.10 ± 23.65	0.40	0.76
TG (mg/dL)	93.32 ± 27.13[3,4]	92.34 ± 27.79[3,4]	189.00 ± 30.41[1,2]	213.52 ± 49.52[1,2]	**< 0.001**	**< 0.001**
SGOT (mg/dL)	17.62 ± 5.48	18.11 ± 7.72	16.29 ± 5.05	18.40 ± 8.41	0.67	0.63
SGPT (mg/dL)	13.93 ± 6.24	20.22 ± 13.92	17.37 ± 8.01	20.09 ± 15.13	0.30	0.62
Body composition parameters						
Weight(cm)	65.88 ± 3.45[2,4]	83.06 ± 11.68[1,3]	65.44 ± 3.01[2,4]	83.85 ± 11.64[1,3]	**< 0.001**	**< 0.001**
Height(cm)	159.26 ± 4.84	161.78 ± 5.79[3]	156.70 ± 4.79[2,4]	161.55 ± 5.96[3]	**< 0.001**	**< 0.001**
BMI (kg/m^2)	25.96 ± 0.86[2,4]	31.76 ± 4.13[1,3]	26.72 ± 1.26[2,4]	32.11 ± 4.12[1,3]	**< 0.001**	**< 0.001**
SMM (kg)	22.08 ± 2.19[2,4]	25.75 ± 3.14[1,3]	22.48 ± 1.95[2,4]	26.26 ± 3.52[1,3]	**< 0.001**	**0.002**

variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWNT	NWET	EWET		
	N = 15	N = 88	N = 14	N = 109		
FFM (kg)	40.81 ± 3.66[2,4]	46.79 ± 5.09[1,3]	41.44 ± 3.39[2,4]	47.73 ± 5.93[1,3]	**< 0.001**	**< 0.001**
WHR	0.86 ± 0.18	1.48 ± 6.98	0.86 ± 0.02	0.94 ± 0.04	0.68	**< 0.001**
WC (cm)	84.66 ± 2.16[2,3,4]	101.74 ± 8.99[1,3]	85.02 ± 1.85[2,4]	101.60 ± 8.97[1,3]	**< 0.001**	**< 0.001**
Qualitative variables						
Economic status						
Poor	2(5.0%)[b]	13(32.5%)	2(5.0%)	20(57.5%)	0.18***	0.65
Moderate	13(7.8%)	30(41.9%)	11(6.6%)	43(43.7%)		
Good	8(5.8%)	27(41.3%)	11(7.1%)	34(45.8%)		
Excellent	1(5.0%)	15(75.0%)	0 (0%)	4(19.99%)		
Education status						
Illiterate	0(0.0%)	1(25.0%)	1(25.0%)	2(50.0%)	0.31	0.88
Diploma	1(2.0%)	17(36.7%)	2(4.1%)	23(57.1%)		
University educated	20(7.0%)	71(43.3%)	19(6.1%)	72(43.6%)		
Marital status						
Single	7(7.3%)	36(52.3%)	4(3.7%)	29(36.7%)	**0.05**	0.47
Married	12(5.9%)	50(38.5%)	18(7.0%)	80(48.6%)		
familial obesity history						
Yes	10 (5.2%)	56 (39.7%)	13 (6.7%)	80 (48.4%)	0.17	0.92
No	9 (9.3%)	31 (47.2%)	6 (5.5%)	21 (38%)		

variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWNT	NWET	EWET		
	N = 15	N = 88	N = 14	N = 109		

NWNT: normal waist normal triglyceride, EWNT: enlarged waist normal triglyceride, NWET: normal waist enlarged triglyceride, EWET: enlarged waist enlarged triglyceride, [a] Mean±SD; [b] N(%), PA: physical activity, HOMA-IR: Homeostatic Model Assessment for Insulin Resistance TC: total cholesterol, HDL-C: high density lipoprotein cholesterol, LDL-C: low density lipoprotein cholesterol, TG: triglyceride, SGOT: serum glutamic-oxaloacetic transaminase, SGPT: Serum glutamic-pyruvic transaminase, BMI: body mass index, SMM: skeletal muscle mass, FFM: fat free mass, WHR: waist to hip ratio, WC: waist circumference

**P value resulted from ANOVA analysis*

*** P value reported after adjusting age, energy intake, BMI and physical activity with ANCOVA analysis*

**** P value resulted from chi-squared test analysis*

Table 3 presents the association between dietary intake components and HTGWCPs. After adjustment confounding variables including; age, energy intake, BMI and physical activity, consumption of saturated fatty acid (SFA), Iron, Manganese, Selenium were higher in EWNT phenotype ($P \leq 0.001$). Women in NWET phenotype consumed higher amount of Glucose, Fructose and Potassium ($P \leq 0.02$) and Sodium, Vitamin K and vitamin C intake were higher in EWET phenotype ($P \leq 0.05$).

Table 3
Dietary intake components among types of hypertrigeliceridemic waist circumference phenotype

Variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWET	NWET	EWET		
Macronutrients						
Energy (kcal/d)	2632.05 ± 728.86[a]	2609.91 ± 848.11	2329.64 ± 769.94	2694.96 ± 785.13	0.20	-
Carbohydrate (gr/d)	365.14 ± 103.22	365.71 ± 126.43	338.33 ± 141.30	384.07 ± 122.92	0.27	0.36
Protein(gr/d)	93.67 ± 27.53	90.81 ± 33.07	76.78 ± 29.22	93.36 ± 30.44	0.10	0.52
Fat(gr/d)	97.13 ± 34.87	95.28 ± 36.96	83.65 ± 30.81	96.26 ± 34.08	0.42	0.72
Fiber(gr/d)	47.78 ± 14.74	46.17 ± 23.16	40.19 ± 18.86	49.29 ± 20.60	0.19	0.73
MUFA (gr/d)	30.62 ± 9.98	32.3 ± 13.75	28.63 ± 12.34	32.38 ± 12.58	**0.54**	0.65
PUFA (gr/d)	19.06 ± 9.12	19.30 ± 9.69	19.24 ± 10.93	21.03 ± 9.31	0.34	0.38
TC (gr/d)	276.80 ± 105.43	270.15 ± 119.82	221.89 ± 83.35	262.44 ± 110.85	0.24	0.34
Saturated fatty acid(gr/d)	28.54 ± 9.09	29.88 ± 12.81	24.36 ± 9.10	27.60 ± 10.77	**0.09**	**0.001**
Trans fatty acid(gr/d)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.99	0.99
Glucose(gr/d)	19.04 ± 8.13	18.13 ± 8.37[4]	22.02 ± 13.31	21.36 ± 12.21[2]	**0.03**	**0.002**
Galactose(gr/d)	2.86 ± 2.25	2.73 ± 2.27	2.68 ± 2.21	2.81 ± 1.87	0.97	0.95
Fructose(gr/d)	23.12 ± 10.69	21.35 ± 9.88[4]	26.64 ± 15.88	25.87 ± 14.12[2]	**< 0.001**	**< 0.001**
Sucrose(gr/d)	28.96 ± 14.45	28.62 ± 18.79[4]	30.07 ± 18.37	34.47 ± 21.37[2]	**0.04**	**0.05**
Micronutrients						
Vitamins						

Variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWET	NWET	EWET		
Vitamin A(mg/d)	720.01 ± 296.62	706.34 ± 364.57[4]	851.04 ± 517.97	808.10 ± 432.03[2]	**0.07**	**0.02**
Vitamin E(mg/d)	14.24 ± 5.76	16.11 ± 8.71	17.05 ± 9.35	18.2 ± 9.55	**0.07**	**0.06**
Vitamin C(mg/d)	185.19 ± 109.74	167.68 ± 89.30	197.27 ± 127.34	206.32 ± 134.57	**0.02**	**0.01**
Vitamin D3(mg/d)	1.68 ± 1.22	1.84 ± 1.61	2.05 ± 1.82	2.08 ± 1.50	0.40	0.38
Thiamin(mg/d)	2.11 ± 0.60	2.17 ± 0.79	1.80 ± 0.72	2.15 ± 0.68	0.14	0.14
Riboflavin(mg/d)	2.23 ± 0.75	2.28 ± 0.89	2.01 ± 0.86	2.30 ± 0.86	0.48	0.89
niacin(mg/d)	26.45 ± 8.20	26.52 ± 10.68[3]	20.95 ± 6.80[2,4]	26.91 ± 10.02[2]	**0.05**	0.22
Vitamin B6(mg/d)	2.18 ± 0.65	2.15 ± 0.78	2.00 ± 0.78	2.26 ± 0.74	0.33	0.83
Folate(µg/d)	600.20 ± 140.00	610.41 ± 208.34	534.08 ± 198.33[4]	643.41 ± 180.83[3]	**0.04**	0.21
Vitamin B12(mg/d)	4.66 ± 2.63	4.37 ± 2.68	4.07 ± 1.96	4.31 ± 2.34	0.86	0.70
Vitamin k(mg/d)	233.20 ± 215.57	231.07 ± 346.74	218.18 ± 166.82	264.13 ± 254.21	**0.07**	**0.05**
Minerals						
Sodium(mg/d)	4405.09 ± 1675.90	4652.73 ± 2006.48[3]	3483.37 ± 1062.23[2,4]	4473.81 ± 1558.14[3]	**0.02**	**0.02**
Potassium(mg/d)	4446.17 ± 1519.91	4415.31 ± 1811.92	4164.52 ± 1952.46	4649.76 ± 1643.91	0.44	0.79
Calcium(mg/d)	1229.25 ± 411.76	1321.56 ± 601.72	1084.00 ± 544.04	1251.04 ± 478.31	0.18	**0.07**
Iron(mg/d)	24.80 ± 14.41	31.96 ± 26.98[2,3]	16.38 ± 6.36[2]	23.01 ± 14.52[2]	**< 0.001**	**< 0.001**
Phosphorus(mg/d)	1666.65 ± 509.34	1672.72 ± 603.78	1480.26 ± 643.90	1703.95 ± 519.27	0.34	0.94

Variables	Hypertriglyceridemic waist circumference phenotypes				P value*	P value**
	NWNT	EWET	NWET	EWET		
Magnesium (mg/d)	455.09 ± 128.57	480.26 ± 189.22	420.49 ± 183.10	481.77 ± 157.76	0.36	0.46
Zinc(mg/d)	13.37 ± 4.20	13.59 ± 5.02	11.42 ± 4.93	13.52 ± 4.80	0.22	0.27
Copper(mg/d)	2.01 ± 0.56	1.97 ± 0.74	1.86 ± 0.66	2.08 ± 0.78	0.35	0.55
Manganese(mg/d)	7.43 ± 2.42	9.00 ± 5.17[3,4]	6.24 ± 3.02[2]	7.52 ± 2.86[2]	**< 0.001**	**< 0.001**
Selenium(mg/d)	122.71 ± 40.08	132.91 ± 56.35[3]	101.51 ± 46.26[2]	124.53 ± 43.47	**0.02**	**0.001**
Other variables						
Caffeine(gr/d)	131.96 ± 88.91	165.39 ± 197.47	130.05 ± 99.22	148.29 ± 103.28	0.50	0.50

NWNT: normal waist normal triglyceride, EWNT: enlarged waist normal triglyceride, NWET: normal waist enlarged triglyceride, EWET: enlarged waist enlarged triglyceride. [a]Mean±SD, MUFA: mono unsaturated fatty acid, PUFA: poly unsaturated fatty acid

**P value resulted from ANOVA analysis*

*** P value reported after adjusting age, energy intake, BMI and physical activity with ANCOVA*

Association of the DII and HTGWCP

The associations between DII and HTGWCPs in crude and adjusted model are shown in Table 4. In crude model a significant correlation was showed between DII and EWNT (OR = 1.8, 95% CI = 0.91 to 3.53, P for trend = 0.08) and EWET (OR = 2.07, 95% CI = 1.07 to 4.01, P for trend = 0.02). In the adjusted model according to energy intake, age, plasma insulin levels, marital status, education, economic status and familial obesity history, we observed that with increasing DII, the odds of having the EWNT (OR = 2.85, 95% CI = 1.02 to 7.98, P for trend = 0.04), NWET (OR = 5.85, 95% CI = 1.1 to 31.11, P for trend = 0.03) and EWET (OR = 3.13, 95% CI = 0.95 to 10.27, P for trend = 0.05) phenotypes were significantly increased compared to NWNT phenotype among participants.

Table 4
Crude model and adjusted model for Relationship between hyper triglyceridemic waist circumference phenotype and DII

	OR (95% CI)	β ± SE	P-trend
Crude model			
EWNT	1.80(0.91_3.53)	0.58 ± 0.34	**0.08**
NWET	1.74(0.78_3.89)	0.55 ± 0.4	0.17
EWET	2.07(1.07_4.01)	0.73 ± 0.33	**0.02**
Adjusted model [a]			
EWNT	2.85(1.02_7.98)	1.04 ± 0.52	**0.04**
NWET	5.85(1.10_31.11)	1.76 ± 0.85	**0.03**
EWET	3.13(0.95_10.27)	1.14 ± 0.6	**0.05**

DII: dietary inflammatory index, OR: odds ratio, CI: confidence interval, SE: standard error, EWNT: enlarged waist normal triglyceride, NWET: normal waist enlarged triglyceride, EWET: enlarged waist enlarged

Normal waist normal triglyceride (NWNT) Consider as reference

[a] adjusted for energy intake, age, plasma insulin levels, marriage status, educational status, economic status and familial obesity history

Discussion

This study was the first cross-sectional study that investigated the association between DII and HTGWCP among overweight and obese women.

We have shown that DII is significantly associated with HTGWCP. Our findings suggested that, increasing DII scores or consuming pro-inflammatory foods can increase the odds of abnormal phenotypes including; EWNT, NWET, EWET phenotypes compared to NWNT phenotype. According to the results of this study; there was a significant correlation between DII and variables including; age (positively), HOMA-IR and TG (negatively) so in this study increased DII did not increase TG and HOMA-IR. However, there was a positive significant relationship between abnormal phenotypes and variables such as insulin, HOMA-IR, TG, weight, height, BMI, SMM, FFM, WHR and WC. We also found positive correlation between abnormal phenotypes and some dietary intake components.

In a cohort study, it was found that the HTGWCP had a similar prevalence to MetS among participants and was associated with the low-grade inflammation seen in obese individuals [28].
Previous studies have shown that obesity and high anthropometric indices such as WC can be a consequence of previous chronic low-grade inflammation. Therefore, there is a relationship between

obesity, especially abdominal obesity and inflammation [25]. Some studies acknowledge that abnormal lipid metabolism plays an important role in the inflammatory response and prognosis of the conditions like obesity and hypertriglyceridemia [26, 27]. In a cohort study, it was found that the HTGWCP had a similar prevalence to MetS among participants and was associated with the low-grade inflammation seen in obese individuals [28]. Many studies, such as a cross-sectional study and the Spanish SUN (Seguimiento Universidad de Navarra) cohort, have been shown that DII was correlated with anthropometric components such as weight and WC, and by increasing this score which indicates a higher consumption of pro-inflammatory foods by Individuals, these indicators have also increased A study has shown that the most pro-inflammatory diet had a stronger association with WC than with other anthropometric indices, both among women and men [4, 29]. Many studies in Western societies suggest that the inflammatory properties of diet are positively associated with predictors of cardiovascular disease, such as increased plasma TG levels and decreased HDL cholesterol concentrations. For example Neufcourt et al. showed in a large (n = 3726) cohort of French adults that after a follow up of 13 years, the DII score was significantly associated with higher triglyceride and lower HDL cholesterol levels [15, 16, 30].

One investigation concluded that among police officers, higher DII scores were associated with elevated high-sensitivity C-reactive protein (hs-CRP) values and the components of MetS[31]. It has been found in several literatures that lower hs-CRP concentration has been associated with a higher intake of some foods and nutrients including; fruits and vegetables [32–34], legumes [35], nuts [36], low-fat dairy consumption [37]fiber intake [38]), vitamin E and vitamin C intake [39]Consumption of some anti-inflammatory foods, including; onion, garlic and tea are associated with improving health status by reducing body fat, increasing the resistance of lipoprotein to oxidation by their antioxidant properties and also increased adiponectin as an anti-inflammatory adipokine and may be effective as a cholesterol-lowering food agents. The high intake of these anti-inflammatory foods may have increased the synergy of anti-inflammatory potential to inhibit the development of MetS components such as hypertriglyceridemia and abdominal obesity [40–42]. Further studies are needed to determine the exact link between anti-inflammatory foods and abdominal obesity and hypertriglyceridemia, and the contribution of each nutrient to the increase of two components.

Current study was the first study to examine the association between DII and HTWCP among obese women and it may represent as a possible novel insight in treatment of obesity and its complications. We evaluated the relationship between some body composition indicators and biochemical parameters and DII, as well as HTGWCP in our study and also we also examined the correlation between some dietary intake components and phenotypes. Studies on women's health have increased in recent years but not enough yet, also, women are known as one of the most sensitive groups in the society, which shows the importance of conducting studies on their health so we selected the women as a target group to help improve their health. We tried to select and adjust some confounders socio-economically because of the correlation between hypertriglyceridemia and abdominal obesity and such factors. Some limitations of the current study should be considered. Briefly, since the study was a cross-sectional study, causality cannot be proven, only correlation, therefore, more studies, especially clinical trial studies, are needed to

investigate this relationship. There may be more socioeconomic factors affecting the sleep quality. We calculated the DII using FFQ that is recognized to had under-reporting or over-reporting bias.

Conclusion

In current study, a significant relationship between DII and HTGWCP was found, and it was shown that an increase in DII scores or higher consumption of pro-inflammatory foods can increase all three abnormal phenotypes (EWNT, NWET, EWET) therefore may lead to an increase in waist circumference and TG concentration among overweight and obese women.

Abbreviations

DII: dietary inflammatory index, WC: waist circumference, HTGWCP: hypertriglyceridemic waist circumference phenotype, TG: triglyceride, BMI: body mass index, FFQ: food frequency questionnaire, NWNT: normal waist normal TG, EWNT: enlarged waist normal TG, NWET: normal waist enlarged TG, EWET: enlarged waist enlarged TG, WHO: World Health Organization, CVD: cardiovascular disease, MeDiet: Mediterranean diet, WHtR: waist-to-height ratio, HDL: high-density lipoprotein, MetSyn: metabolic syndrome, SMM: skeletal muscle mass, FFM: Fat free mass, WHR: waist hip ratio, HC: hip circumference, ELISA: enzyme-linked immunosorbent assay, T-chole: Total cholesterol, LDL: Low-density lipoprotein, IFCC: International Federation of Clinical Chemistry and Laboratory Medicine, SGOT: serum glutamic-oxaloacetic transaminase, SGPT: Serum glutamic-pyruvic transaminase, HOMA-IR: Homeostatic model assessment for insulin resistance, IPAQ: validated International physical activity questionnaire, MET: metabolic equivalent, T: Tertile, ANOVA: analysis of variance, ANCOVA: Analysis of covariance, SFA: saturated fatty acid, hs-CRP: high-sensitivity C-reactive protein

Declarations

Acknowledgement

This study was supported by Tehran University of Medical Sciences Grant (ID: 98-3-212-46728). We thank all the participants in this study, as well as the school of Nutritional and Dietetics at Tehran University of medical sciences.

Conflicts of interest

The authors declare that there is no conflict of interest in this study.

Ethics approval and consent to participate

The study protocol was approved by the ethics committee of Tehran University of medical sciences (IR.TUMS.MEDICINE.REC.1399.636) and is acknowledged by authors. All participants signed a written informed consent.

Funding

This study was supported by Tehran University of Medical Sciences (Grant No: 98-3-212-46728)

Participant consent

All participants signed a written informed consent

Authors' contributions

Atefeh Tavakoli, Atieh Mirzababaei, Hanieh Moosavi and Sanaz Mehranfar, contributed to conception and design. Atefeh Tavakoli and Atieh Mirzababaei, Contributed to all experimental work. Atefeh Tavakoli and Atieh Mirzababaei, Contributed to data and statistical analysis. Khadijeh Mirzaei and Seyed-Ali Keshavarz supervised the whole project. All authors performed editing and approving the final version of this paper for submission, also participated in the finalization of the manuscript and approved the final draft.

Availability of data and materials

The data that support the findings of this study are available from Dr.Khadijeh Mirzaei but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Dr. Khadijeh Mirzaei.

Consent for publication

All authors performed editing and approving the final version of this paper for submission, also participated in the finalization of the manuscript and approved the final draft

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